



Virtual Compton Scattering at Jefferson Lab: preliminary results at $Q^2 = 1.$ and 1.9 GeV^2

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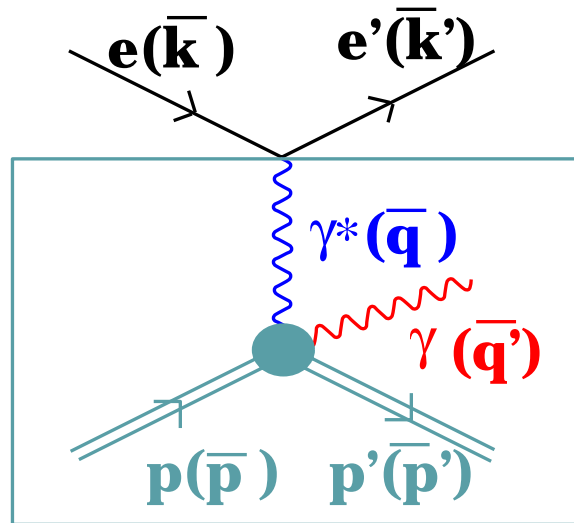
Virtual Compton Scattering at JLab : Preliminary results $Q^2 = 1.$ and 1.9 GeV^2

E93050 collaboration
for the hall A Collaboration of Jefferson Lab.

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IN2P3-CNRS

SANTORINI 2001
Electromagnetic Interactions with Nucleons
and Nuclei
2-7 october 2001

Virtual Compton Scattering below π^0 threshold



hadronic system $\gamma^* p \rightarrow \gamma p$

$$\bar{q} = (\bar{k} - \bar{k}') \quad \text{and} \quad Q^2 = -\bar{q}^2$$

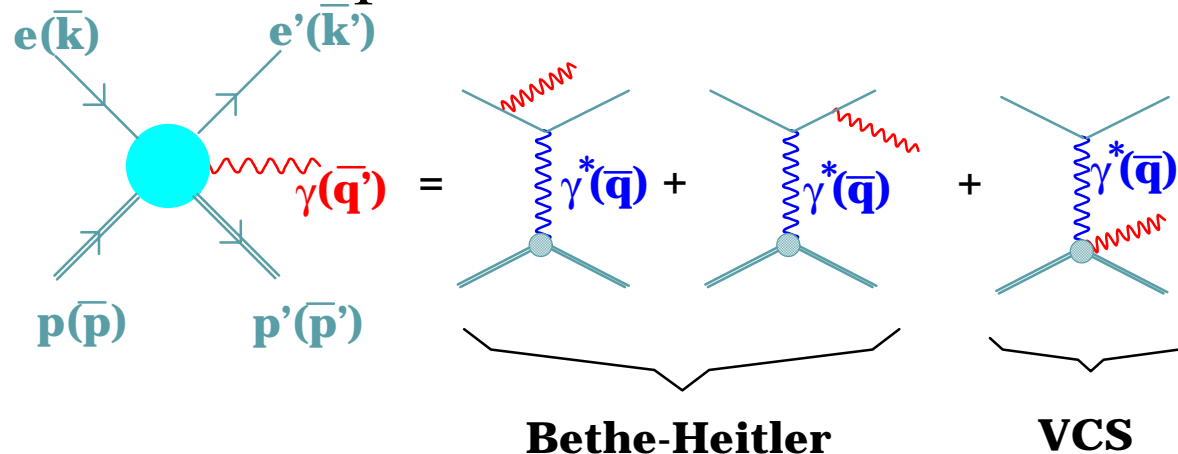
- Real Compton Scattering ($\gamma p \rightarrow \gamma p$) $\alpha, \beta (Q^2 = 0)$
- Virtual Compton Scattering : $\alpha, \beta (Q^2 \neq 0) + \text{new observables}$

**Generalized Polarizabilities
of the nucleon**

goal : to constrain models of nucleon structure at low energy

Generalized Polarizabilities

- Photon electroproduction is the coherent sum of 2 processes



- VCS : γ is emitted by

▲ **nucleon** : **Born term** entirely calculable

(proton electromagnetic form factors : G_E^P and G_M^P)

▲ **excited state** : **Non Born term** : UNKNOWN

➔ photon electroproduction amplitude :

$$T^{ep\gamma} = \underbrace{T^{BH}}_{\text{calculable}} + \underbrace{T^B + T^{NB}}_{\text{unknown (GPs)}}$$

P Guichon : develop amplitude in polynomial of q'_{cm}

(q'_{cm} = outgoing photon momentum in $(\gamma^* p)$ center mass)

(P. Guichon and M. Vanderhaegen, Prog.Part. Nucl. Phys. **41** (1998) 125)

Low Energy Theorem (F.E. Low, Phys. Rev. **96** (1954) 1428)

$$d^5 \sigma^{ep\gamma} = d^5 \sigma^{BH+B} + \underbrace{\Phi q'_{cm}}_{\text{phase space factor}} [M_O - M_O^{BH+B}] + O(q'^2_{cm})$$

phase space factor

- $(M_O - M_O^{BH+B})$ is the **lowest order term** containing an effect of Generalized Polarizabilities (known combination)

- 6 GPs are needed to describe $T^{ep\gamma}$

(D.Drechsel *et al*, Phys. Rev. **C55** (1997) 424)

- 5 GPs in unpolarized case, and we extract two structure functions

$$P_{LL} - \frac{1}{\epsilon} P_{TT} \text{ and } P_{LT} \text{ at given } Q^2$$

Photon electroproduction cross section

BH+B cross section

G_M^P : Bosted parametrisation
(P.E. Bosted, Phys. Rev. **C51** (1995) 409)

G_E^P : ratio measured at Jefferson Lab :

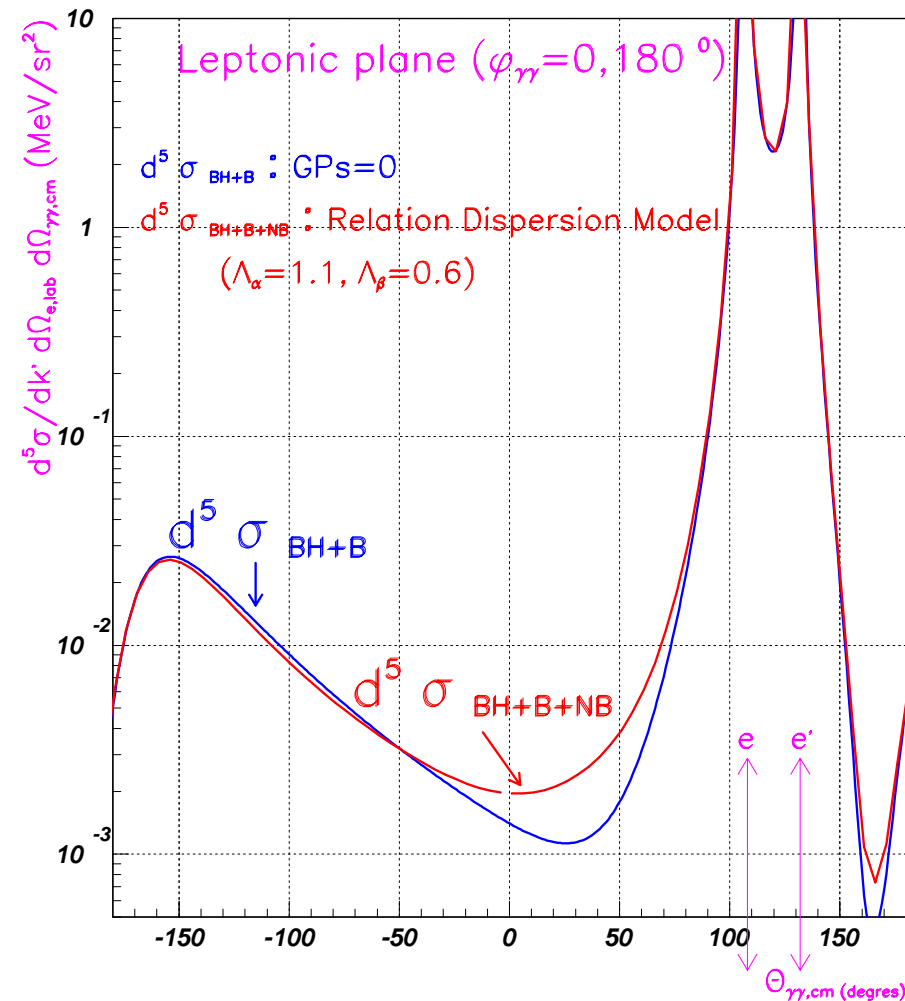
$$\frac{\mu_P G_E^P(Q^2)}{G_M^P(Q^2)}$$

 (M.K. Jones, *et al*, Phys. Rev. Lett. **84** (2000) 1398)

Dispersion Relation formalism

D. Drechsel,
M. Gorchtein,
A. Metz,
B. Pasquini,
M. Vanderhaegen

$q_{cm}=1600 \text{ MeV}/c$, $\varepsilon=0.88$, $q'_{cm}=105 \text{ MeV}/c$, $Q^2=1.9 \text{ GeV}^2$



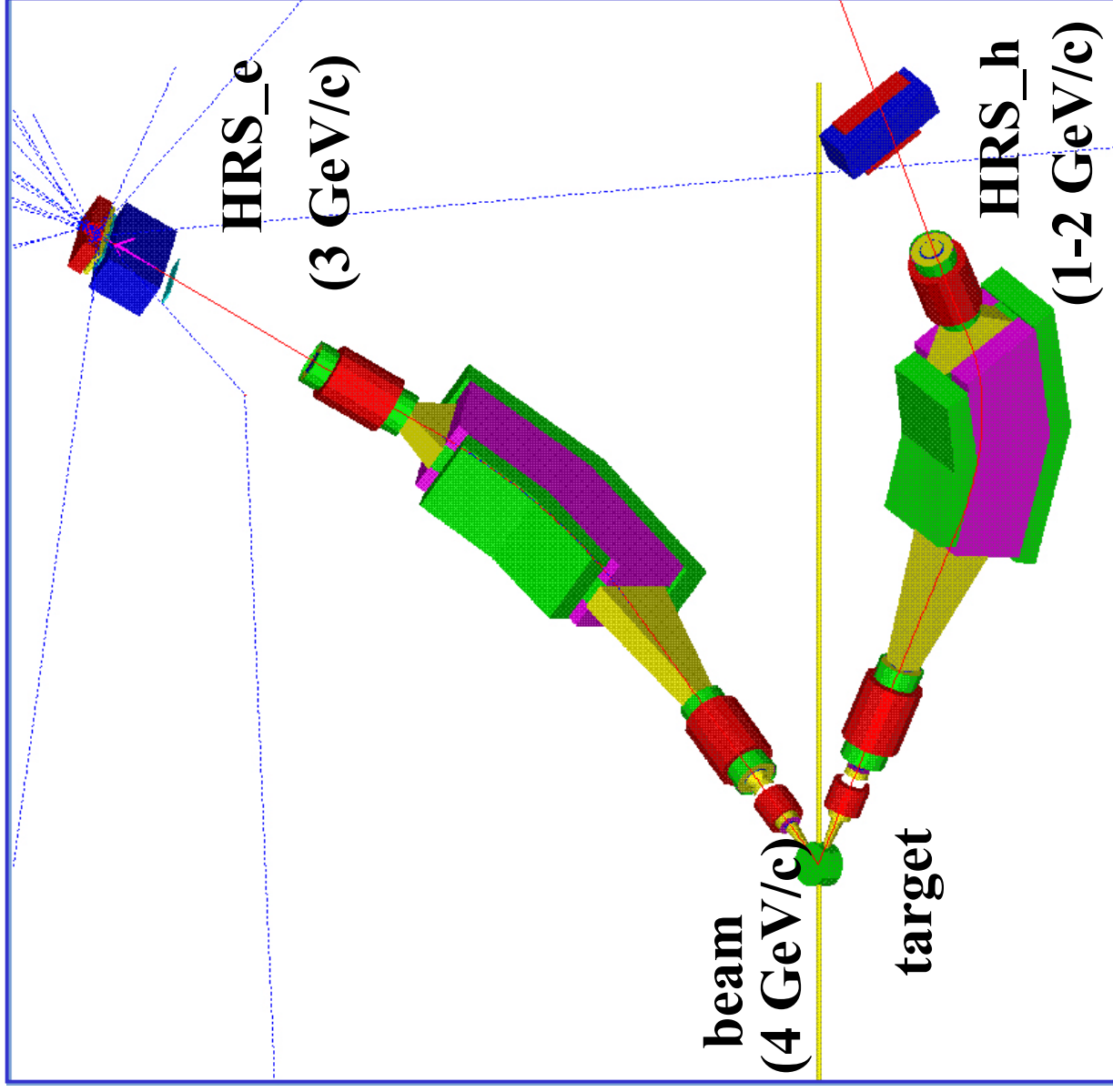
$$\theta_{\gamma\gamma cm} \in [-260^\circ, +100^\circ]$$

5

VCS experiments

- 1st experiment at Mami (1995-1997)
Generalized Polarizabilities at $Q^2 = 0.33 \text{ GeV}^2$
(J. Roche, *et al*, Phys. Rev. Lett. **85** (2000) 708)
- 2nd experiment at **Jefferson Lab** (march-april 1998)
 - ▲ Generalized Polarizabilities at $Q^2 = 1$ and 1.9 GeV^2
 - ▲ VCS in resonance region
- 3rd experiment at **Bates** at $Q^2 = 0.05 \text{ GeV}^2$ (2000)
- 4th experiment at **Bates** in resonance region (2001)

Jefferson Lab : Hall A



Spectrometer resolution at target (FWHM) :

dispersive angle (vertical)

$$\theta_{tg} : 2 \text{ mrad}$$

transverse angle (horizontal)

$$\phi_{tg} : 0.6 \text{ mrad}$$

transverse coordinate

$$y_{tg} : 1.5 \text{ mm}$$

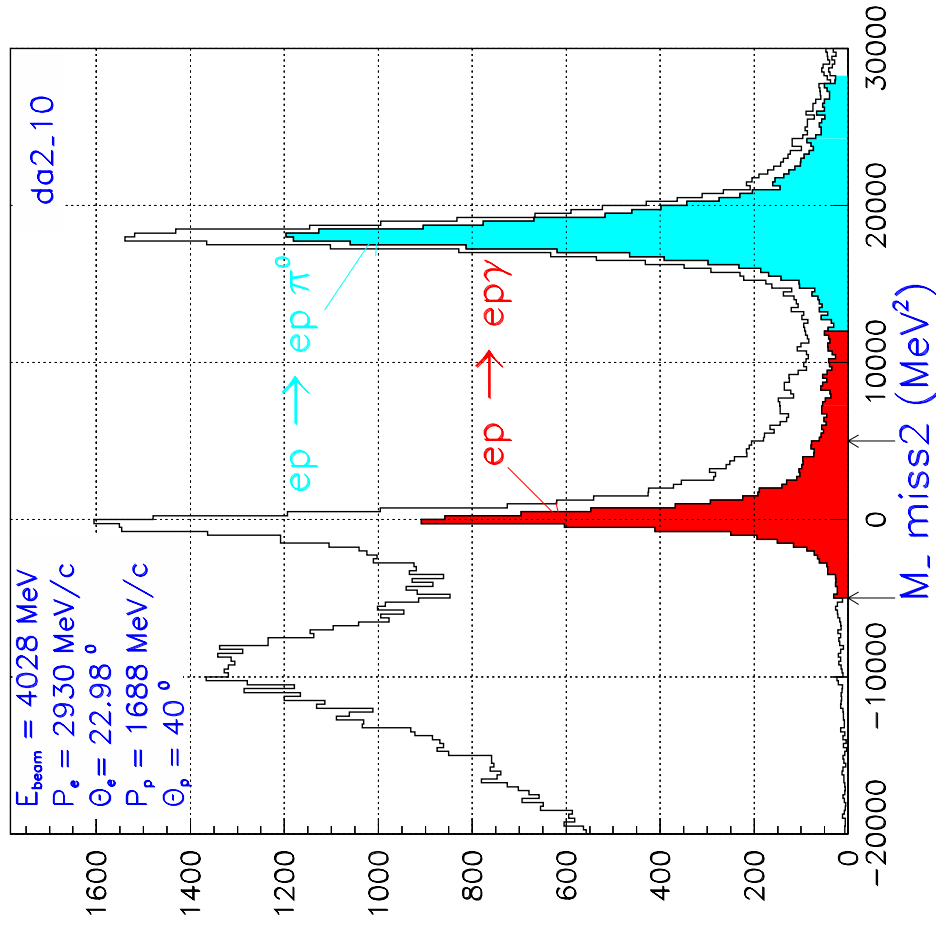
relative momentum

$$\delta : 1.10^{-4}$$

Missing mass for events in coincidence

electron and proton are detected in coincidence

→ γ is a missing particle



Kinematic conventions

VCS below π^0 threshold : momentum of outgoing photon

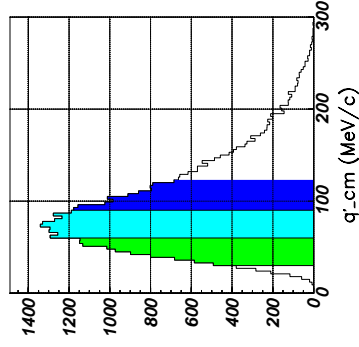
$$q'_{cm} \leq 126 \text{ MeV}/c$$

- 3 bins in q'_{cm}

$$q'_{cm} \in [30, 60] \text{ MeV}/c$$

$$q'_{cm} \in [60, 90] \text{ MeV}/c$$

$$q'_{cm} \in [90, 120] \text{ MeV}/c$$

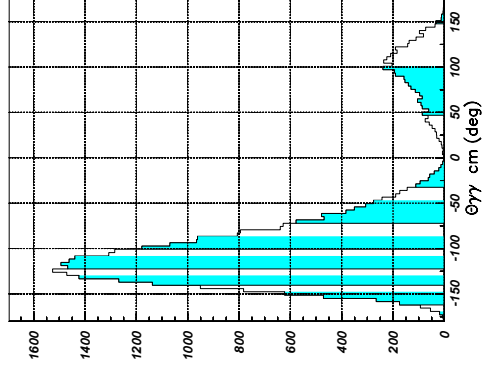


and we have data above
 π^0 threshold at

$$Q^2=1 \text{ and } 1.9 \text{ GeV}^2$$

- 18 bins in in-plane

angle $\theta_{\gamma\gamma cm}$



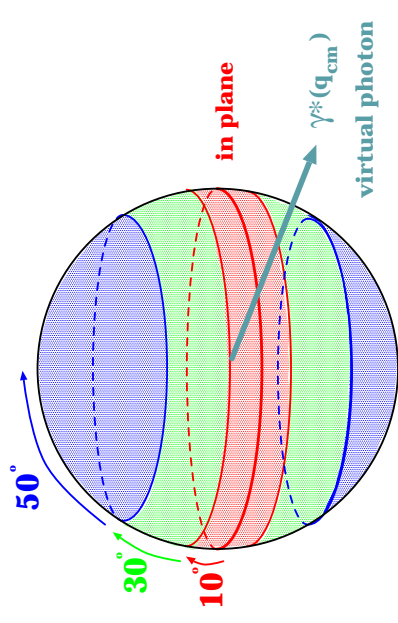
- 3bin in out-of-plane

angle

$$[0^\circ:50^\circ]$$

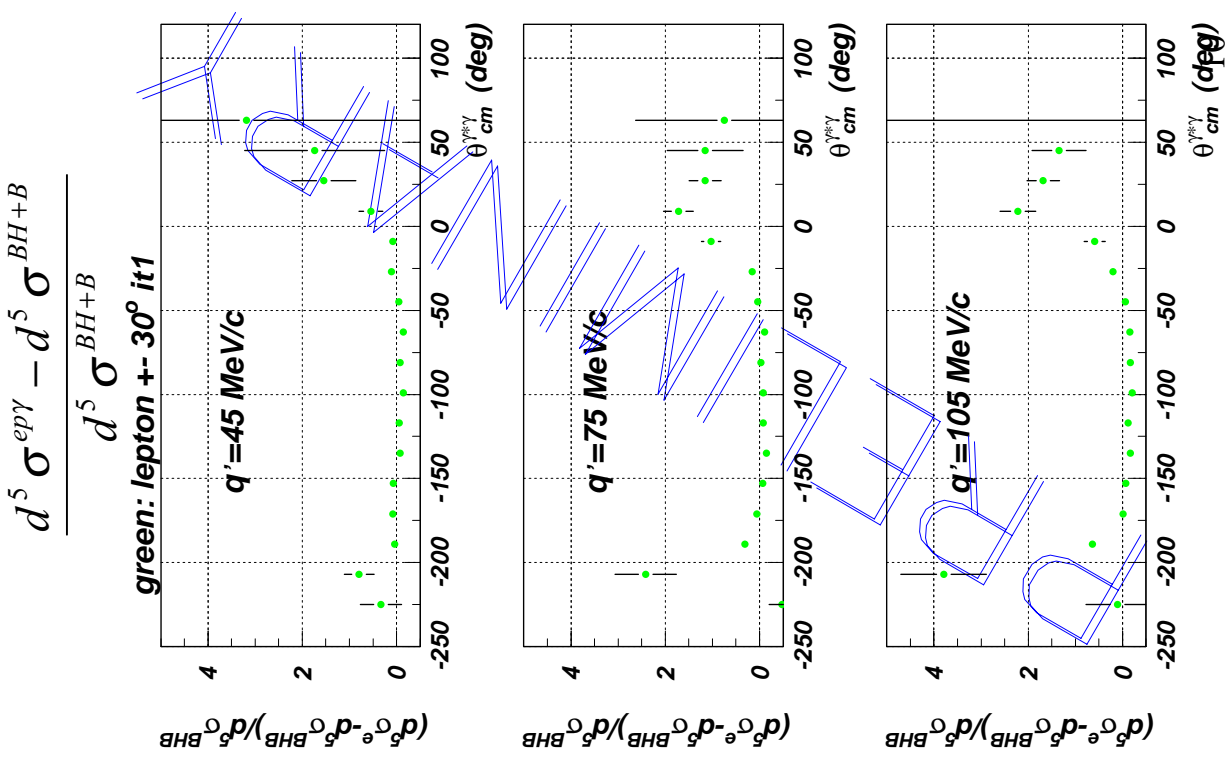
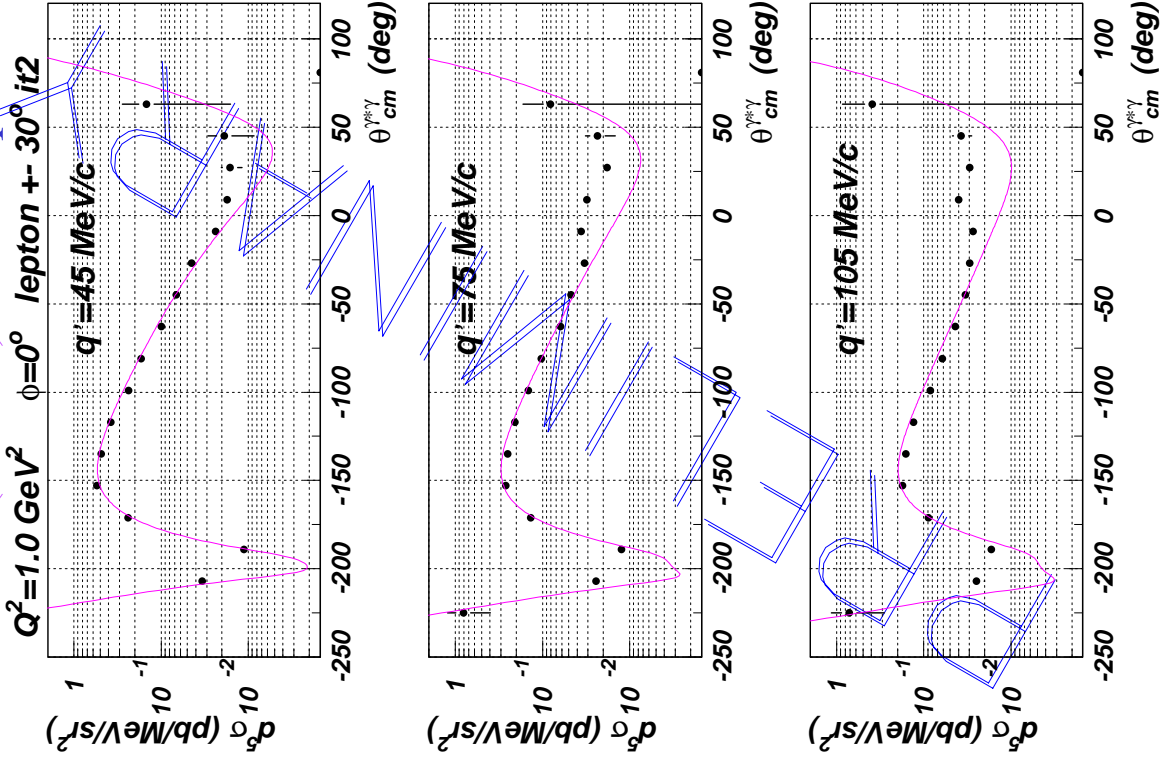
$$[50^\circ:80^\circ]$$

$$[80^\circ:90^\circ]$$



Cross section and ratio at $Q^2 = 1.0 \text{ GeV}^2$

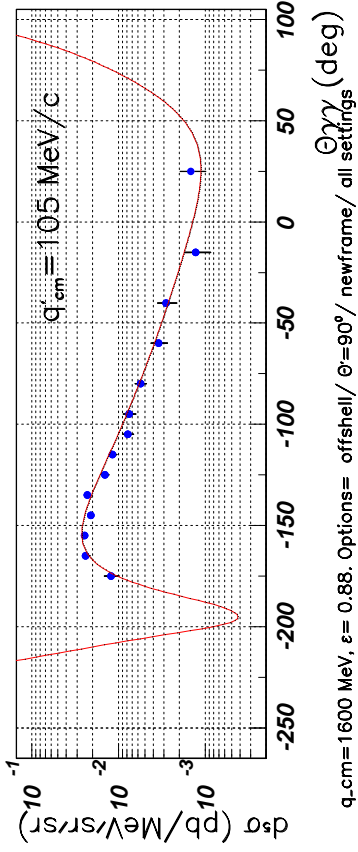
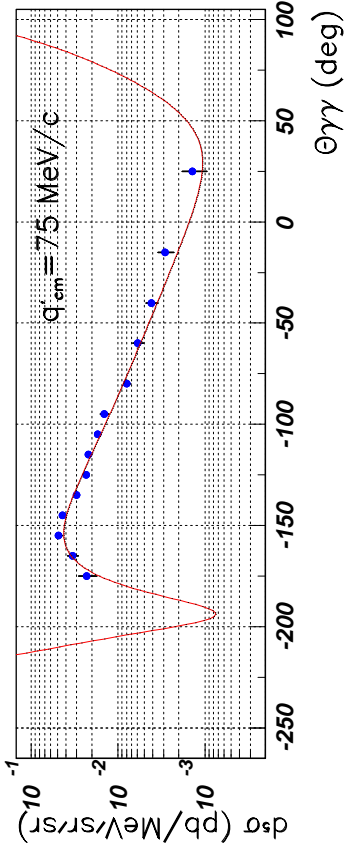
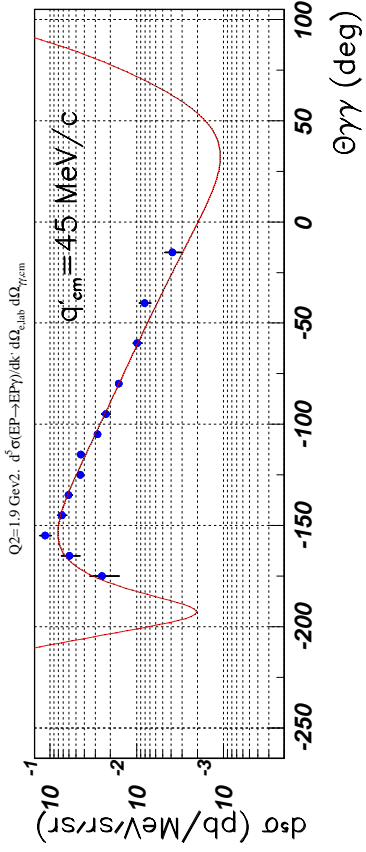
— BH+Bom (GPs=0) • experimental



Cross section and ratio at $Q^2 = 1.9 \text{ GeV}^2$

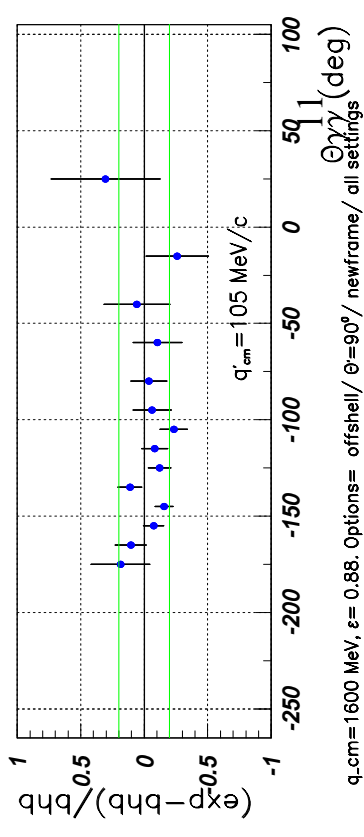
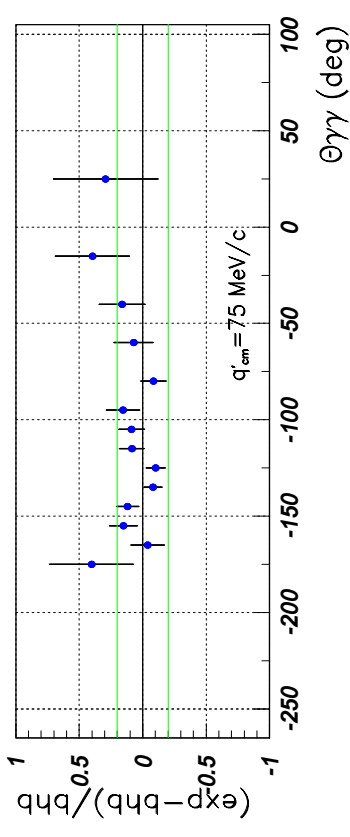
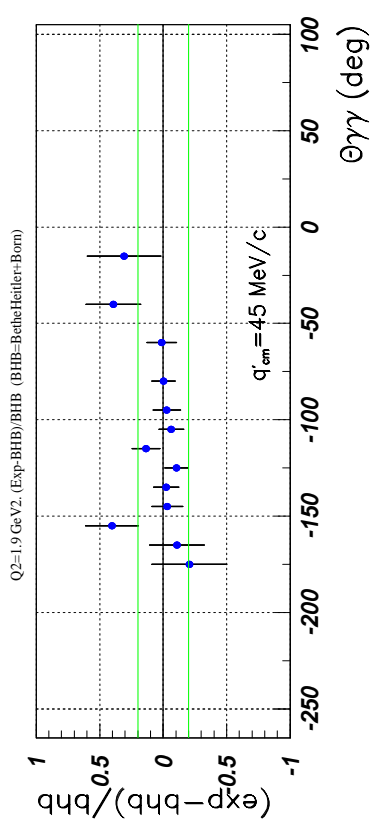
— BH+Born (GP s=0) • experimental

$$\frac{d^5 \sigma^{ep\gamma} - d^5 \sigma^{BH+B}}{d^5 \sigma^{BH+B}}$$



q_{cm}=1600 MeV, $\epsilon = 0.88$. Options= offshell/ $\Theta = 90^\circ$ / newframe/ all settings

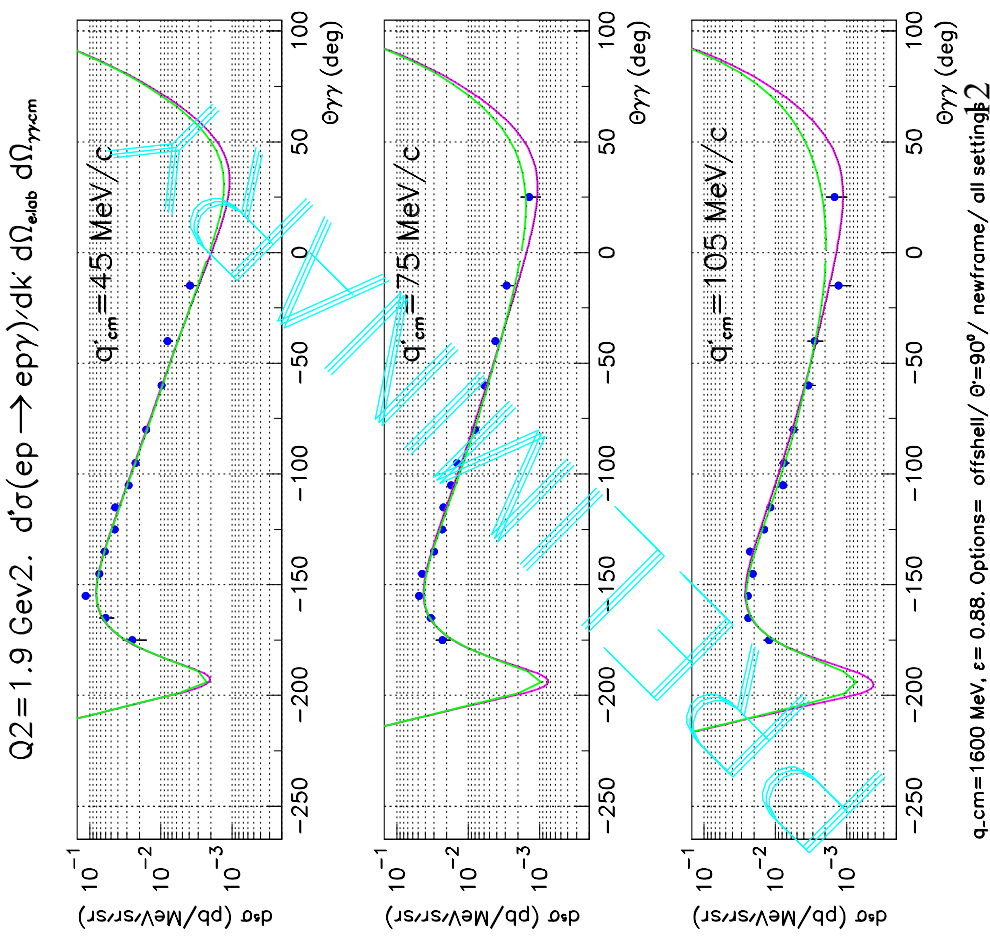
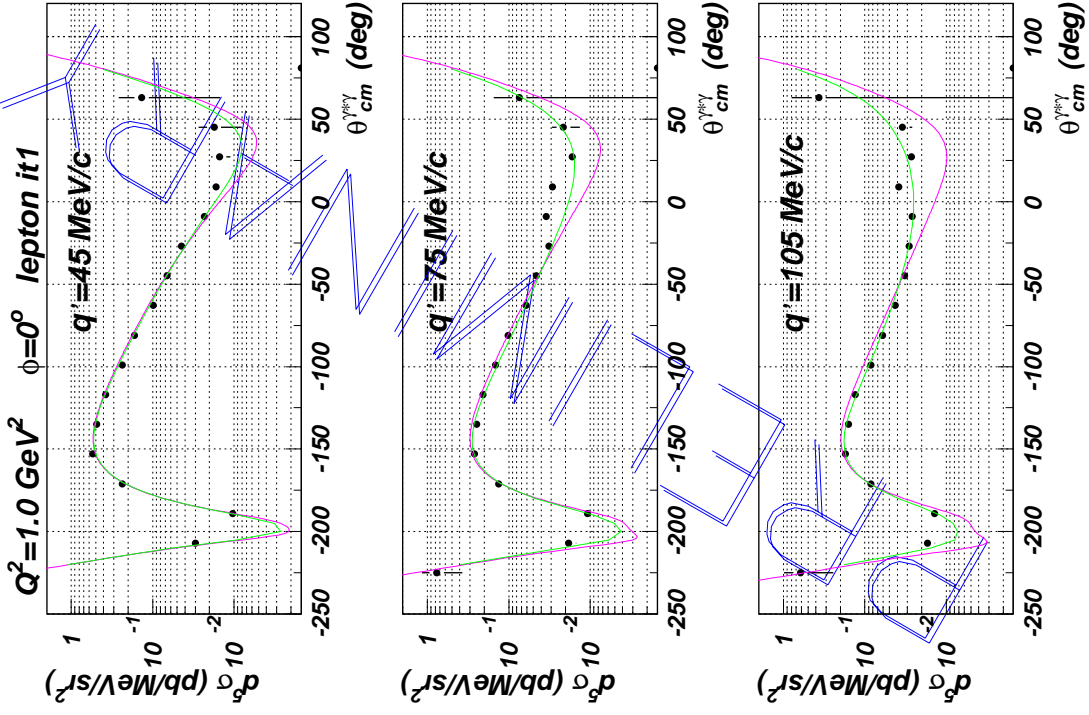
Santorini2001 jaminion@clermont.in2p3.fr



q_{cm}=1600 MeV, $\epsilon = 0.88$. Options= offshell/ $\Theta = 90^\circ$ / newframe/ all settings

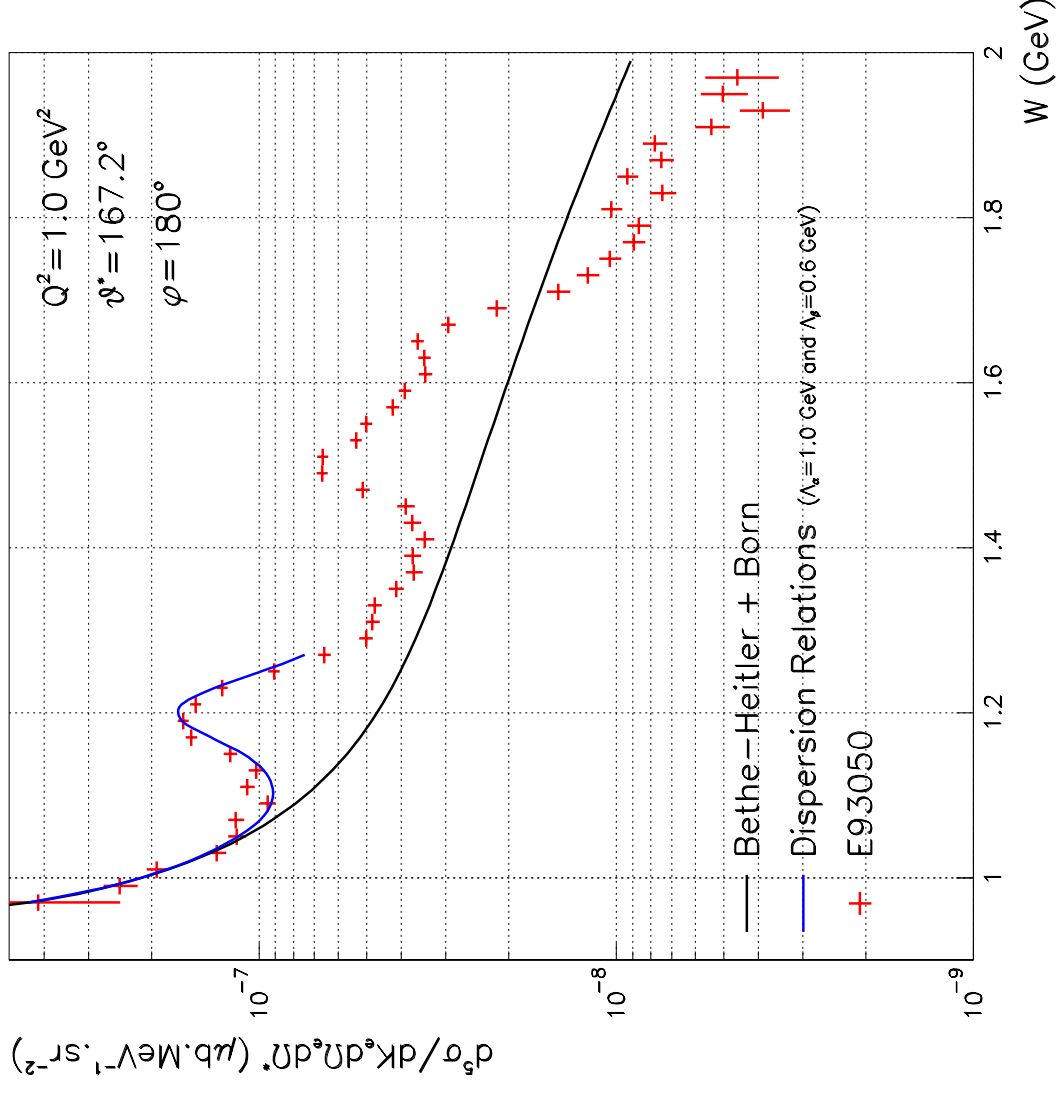
Cross section at $Q^2 = 1.0 \text{ GeV}^2$ and $Q^2 = 1.9 \text{ GeV}^2$

- BH+Born (GPs=0)
- Dispersion Relation Formalism

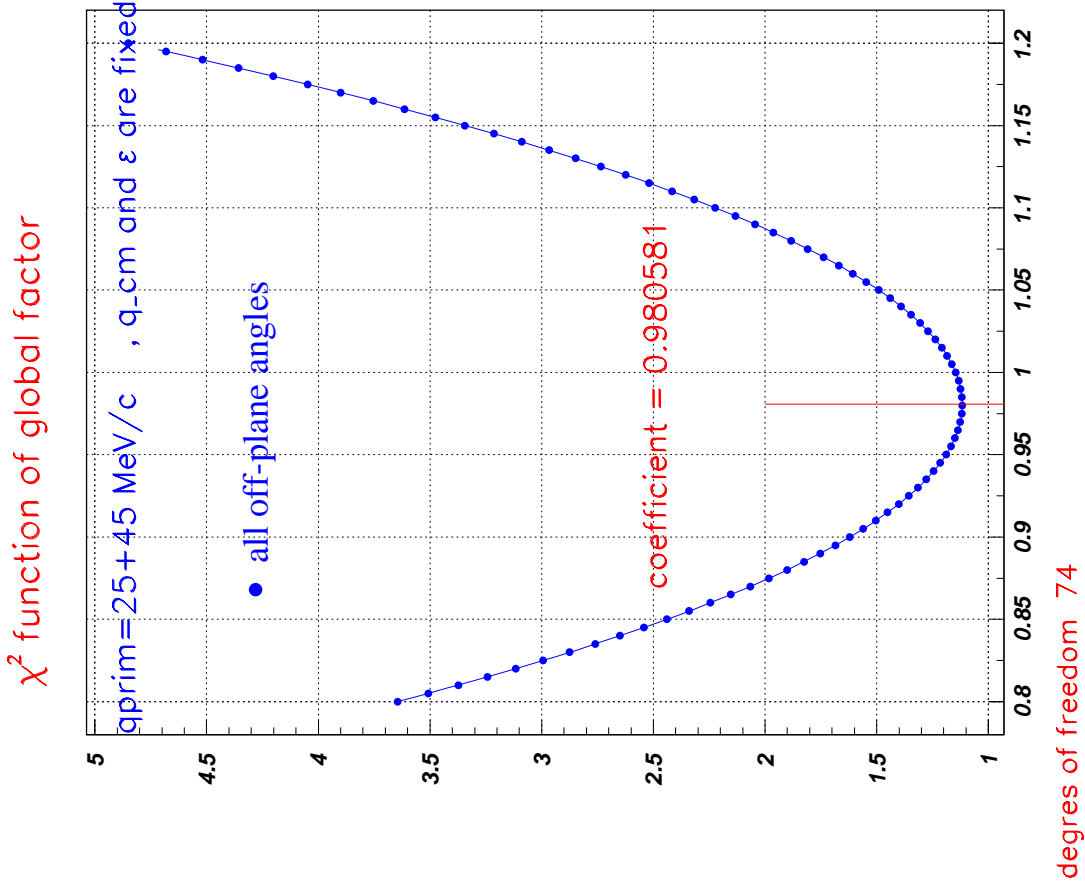


Virtual Compton Scattering in resonance region

for the Hall A collaboration



Global normalization factor at $Q^2 = 1.9 \text{ GeV}^2$



$$\chi^2 = \frac{1}{N} \sum_{i=1}^N \frac{\left(d^5 \sigma_{\text{exp}} - d^5 \sigma_{BH+B} \right)^2}{\left(\Delta d^5 \sigma_{\text{exp}} \right)^2}$$

Generalized Polarizabilities

Photon electroproduction cross section five fold differential :

$$d^5 \sigma^{ep\gamma} = d^5 \sigma^{BH+B} + \Phi q'_{cm} \underbrace{[M_0 - M_0^{BH+B}]}_{\Delta M_0} + O(q'^2_{cm})$$

$M_0 - M_0^{BH+B}$: contains the Generalized Polarizabilities

$$M_0 - M_0^{BH+B} = \nu_{LL} \left(P_{LL}(q_{cm}) - \frac{1}{\varepsilon} P_{TT}(q_{cm}) \right) + \nu_{LT} P_{LT}(q_{cm})$$

kinematic coefficients

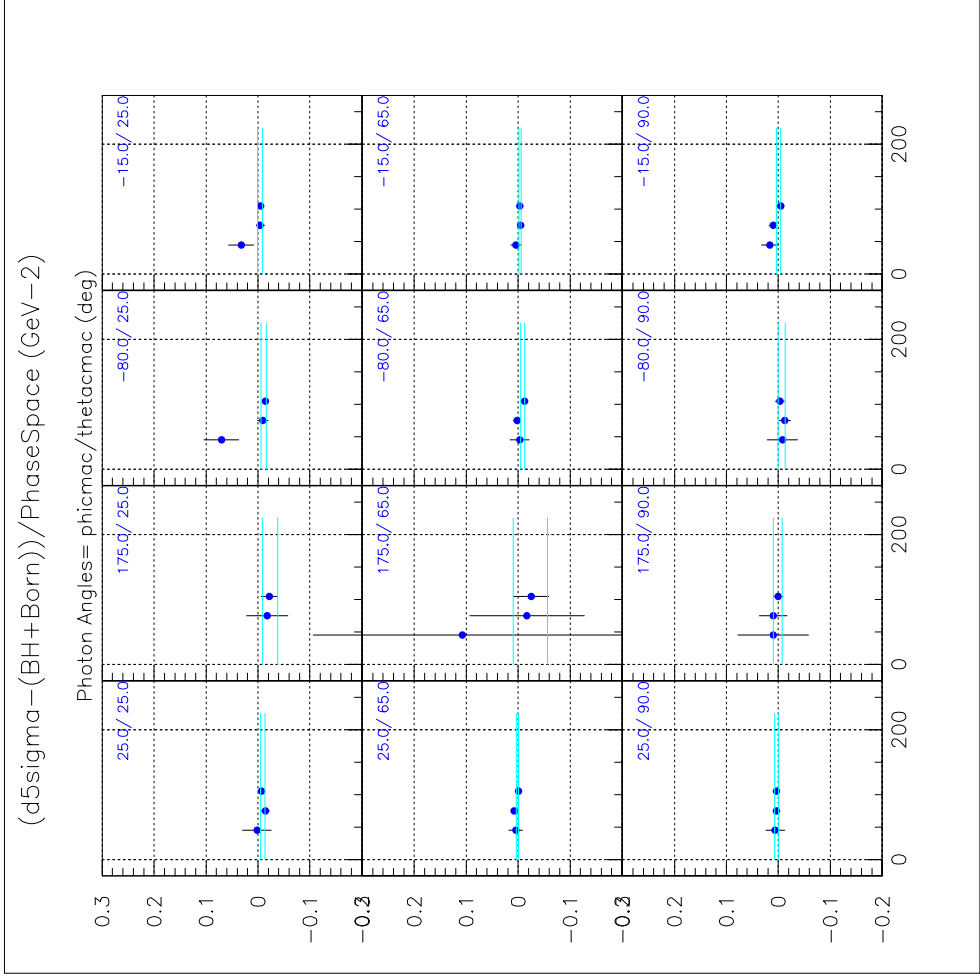
Extrapolation at $q'_{\text{cm}} = 0 \text{ MeV/c}$ at $Q^2 = 1.9 \text{ GeV}^2$

ordinate : $\Delta M = \frac{d^5\sigma_{\text{exp}} - d^5\sigma_{BH+B}}{\Phi q'_{\text{cm}}}$

abscissa : q'_{cm}

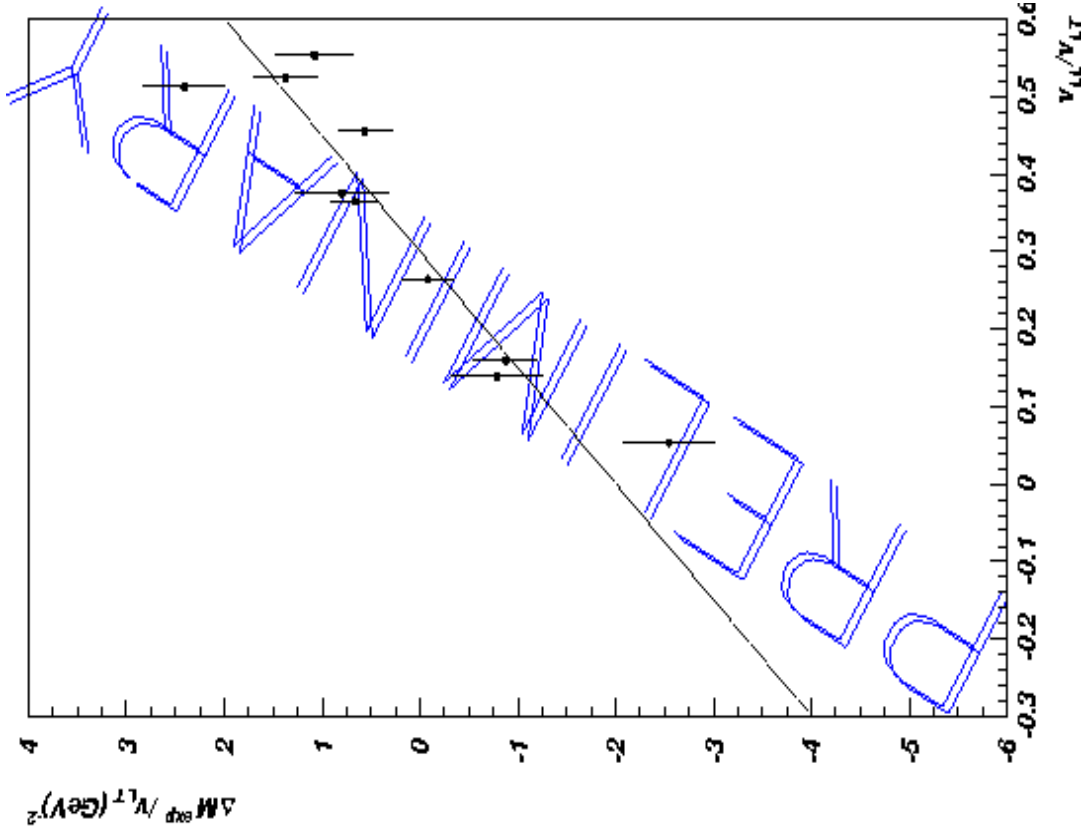
below π^0 threshold :

extrapolation by a constant

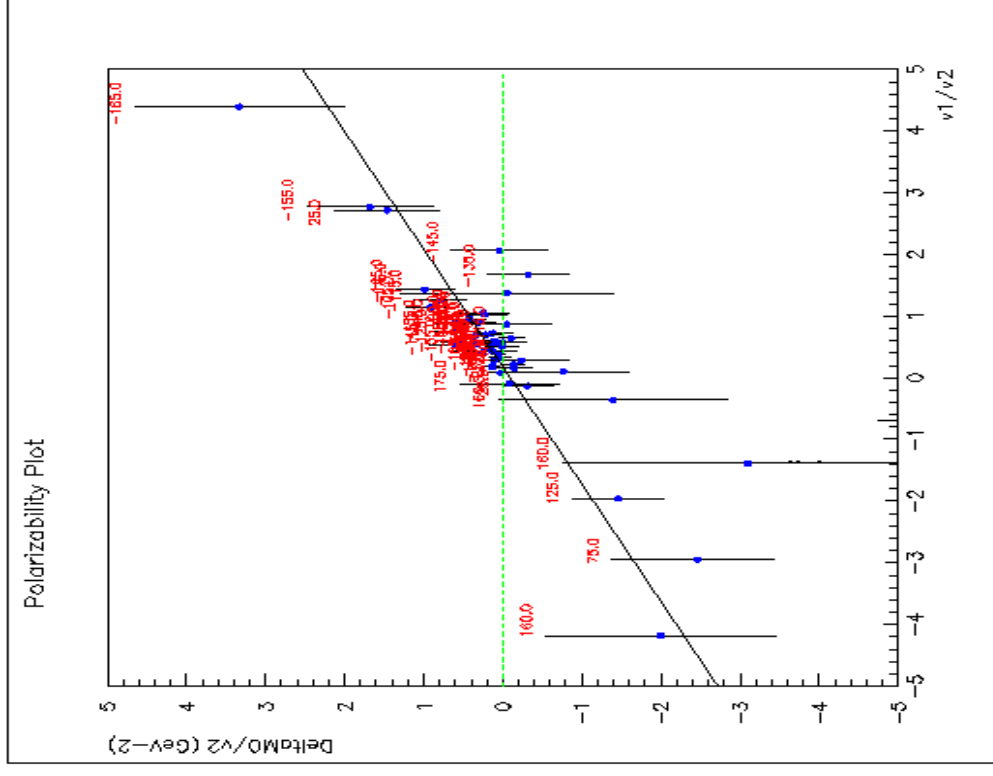


Generalized Polarizabilities extraction

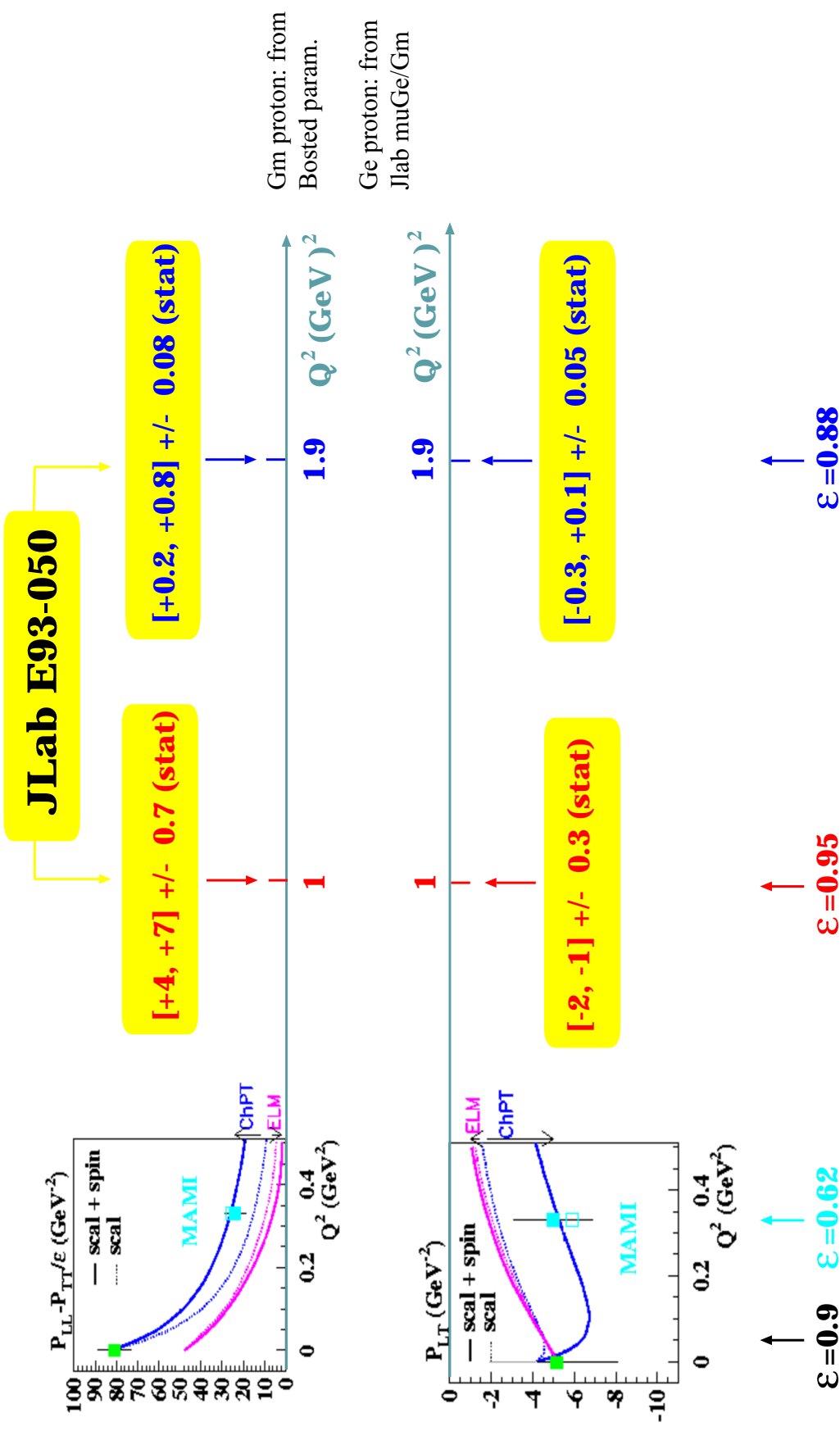
at $Q^2=1.0 \text{ GeV}^2$



at $Q^2=1.9 \text{ GeV}^2$



Preliminary values of Generalized Polarizabilities



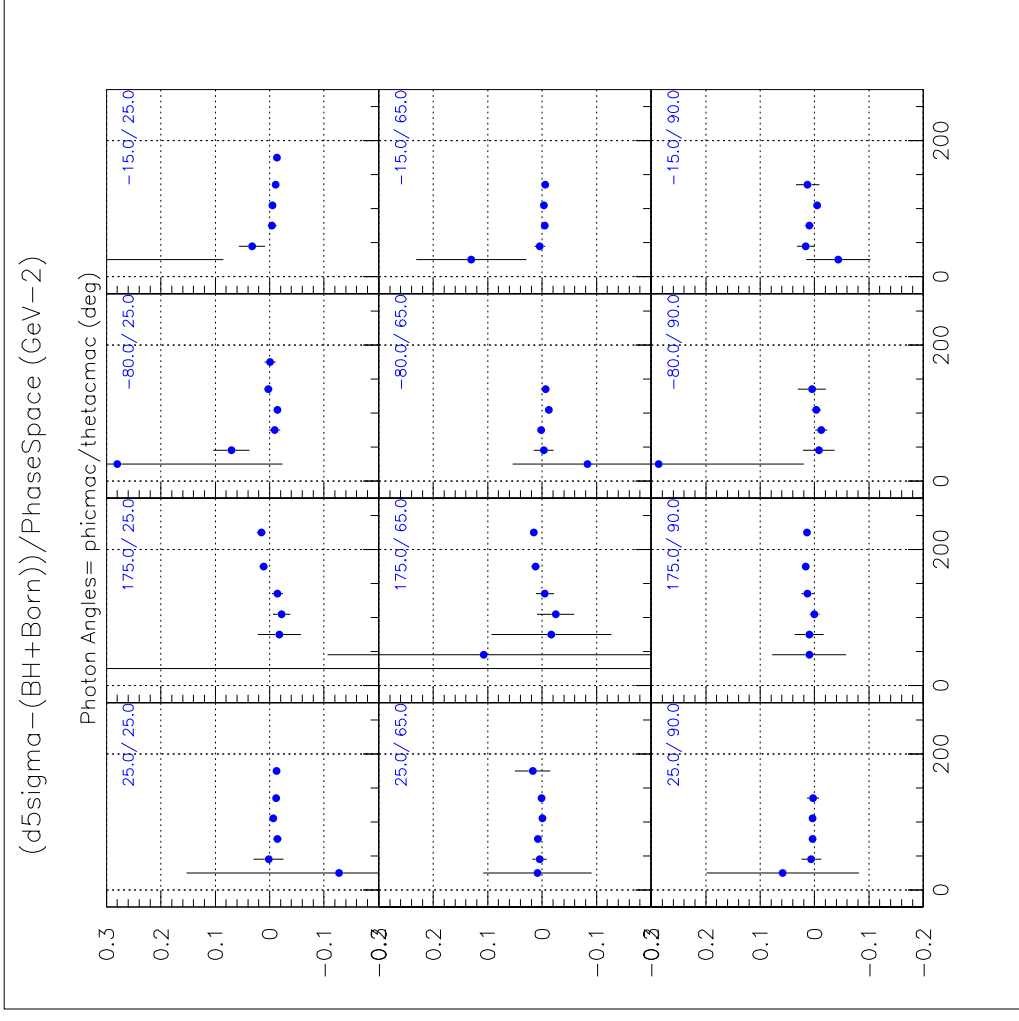
Conclusion

- first extraction of Generalized Polarizabilities

$$P_{LL} - \frac{1}{\varepsilon} P_{TT} \text{ and } P_{LT} \text{ at } Q^2 = 1 \text{ and } 1.9 \text{ GeV}^2$$

- we have to determine the systematic errors
- other approach using data below *and* above π^0 threshold together with dispersion relation formalism

ΔM below and above π^0 threshold



Ratio at $Q^2 = 1.0 \text{ GeV}^2$

$$\frac{d^5 \sigma^{ep\gamma} - d^5 \sigma^{BH+B}}{d^5 \sigma^{BH+B}}$$

— Dispersion Relation Formalism

- experimental

